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PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

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INDICE

1 Introduction

This report describes the design of the bearings. The bearings are based on the design shown in the tender drawings and the 80 day submittal, but for some of the bearings it is found advantageous to introduce the following modification to the design.

- Bearings A5, A6, A7, A9, A13 and A14 experience high uplift forces. In the Progetto Definitivo these bearings are designed with an upper and lower bearing structure. The lower structure houses the normal bearing while the upper part has two uplift bearings connected together by a hydraulic system facilitating a constant and equally shared uplift on both uplift bearings.
- In the tender design seismic isolation in the transverse direction was included by means of hydraulic buffers between the superstructure and substructure of the terminal structure. This, however, results in relative large lateral movements of the terminal superstructure during seismic events, which would be difficult to accommodate in the adjacent viaducts to meet the requirement of uninterrupted road- and rail trafic. In the Progetto Definitivo the transverse buffers have been replaced by a lateral fixation of the terminal superstructure in form of a horizontal guide located at the centre of the substructure cross beam.
- In the tender design seismic isolation in the longitudinal direction was included by means of hydraulic buffers between the superstructure and substructure of the terminal structure. This, however is not accepted by Italien Railway athorities. In the Progetto Definitivo the longitudinal buffers have been replaced by a lateral fixation of the terminal superstructure by changing the ealier free sliding bearing A6 and A7 to guided bearings.

The calculations are prepared by Mageba and are enclosed in the Appendix.

1.1 Report Outline

This report is organized into the following sections:

- Section 1 includes this introduction;
- Section 2 provides a list of reference materials, including design specifications, design codes, material specifications and reference drawings;

- Section 3 provides descriptions of the materials that are used for each component;
- Section 4 describes the output from IBDAS and how it is used in relation to the bearings;
- Detailed design verifications are included in Appendix.

2 Design References

2.1 Design Specifications

1 CG.10.00-P-RG-D-P-GE-00-00-00-00-00-02 - “Design Basis, Structural, Annex,” COWI 2010

2 GCG.F.05.03 “Design Development – Requirements and Guidelines,” Stretto di Messina, 2004 October 22.

3 GCG.G.03.02 “Structural Steel Works and Protective Coatings,” Stretto di Messina, 2004 July 30.

2.2 Design Codes

4 “Norme tecniche per le costruzioni,” 2008 (NTC08).

5 EN 1993 Eurocode 3: Design of Steel Structures – Part 1-1: General rules and rules for buildings

6 EN 1993 Eurocode 3: Design of Steel Structures – Part 1-5: Plated structural elements

7 EN 1993 Eurocode 3: Design of Steel Structures – Part 1-8: Design of joints

8 EN 1993 Eurocode 3: Design of Steel Structures – Part 1-9: Fatigue

9 EN 1993 Eurocode 3: Design of Steel Structures – Part 1-10: Selection of steel for fracture toughness and through thickness properties

10 EN 1993 Eurocode 3: Design of Steel Structures – Part 2: Steel Bridges

11 EN 1998 Eurocode 8: Design of structures for earthquake resistance

12 RFI/DIN/IC/PO 002 A: Istruzione Tecnica 44/E

2.3 Material Specifications

13 EN 10025-1:2004 Hot-rolled products of structural steels – Part 1: General delivery conditions.

14 EN 10025-2:2004 Hot-rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels.

15 EN 10025-3:2004 Hot-rolled products of structural steels – Part 3: Technical delivery conditions for normalized / normalized weldable fine grain structural steels.

16 EN 10025-4:2004 Hot-rolled products of structural steels – Part 4: Technical delivery conditions for thermo mechanical rolled weldable fine grain structural steels.

17 EN 10164:1993 Steel products with improved deformation properties perpendicular to the surface of the product – Technical delivery conditions.

18 EN ISO 898-1:2001 Mechanical properties of fasteners made of carbon steel and alloy steel – Part 1: Bolts, screws and studs (ISO 898-1:1999).

19 EN 20898-2:1994 Mechanical properties of fasteners – Part 2: Nuts with special proof load values – coarse thread (ISO 898-2:1992).

20 UNI EN 14399:2005-3 High-strength structural bolting assemblies for preloading - Part 3: System HR - Hexagon bolt and nut assemblies

2.4 Complementary Reports

21 CG.10.00-P-RG-D-P-SV-00-00-00-00-00-01 - "Global IBDAS Model, Description", COWI 2010

22 CG.10.00-P-SP-D-P-SS-A0-AP-00-00-00-01 - "Performance Specification - Bridge Bearings", COWI 2010

23 CG1000-P-RX-D-P-SS-A0-00-00-00-00-01 - "Articulation System - Specialist Technical Design Report", COWI 2010

2.5 Drawings

The drawings relevant for this report are the following:

24 CG1000-P-AX-D-P-SS-A0-00-00-00-00-01, Articulation system - General arrangement,

25 CG1000-P-AX-D-P-SS-A0-00-00-00-00-02, Articulation system - Support of suspended deck at towers

26 CG1000-P-DX-D-P-SS-A0-AP-00-00-00-01, Articulation system - Bridge bearings, Overview

27 CG1000-P-BX-D-P-SS-A0-AP-00-00-00-01, Articulation system - Bridge bearings, Details

3 Materials

The design of the bearings is carried out by the manufacturers based on technical performance specifications issued as a part of the Progetto Definitivo. The mechanical properties of the applied materials can be found in the manufacturers' documentation.

4 Design Principles

4.1 FE-Model

A 3D computer model has been established using the in-house software program IBDAS. IBDAS (Integrated Bridge Design and Analysis System) is a general software package for structural design and analysis developed by COWI. IBDAS is based on 3D logical parametric solid modelling and provides procedures for fully integrated design and analysis of load bearing structures.

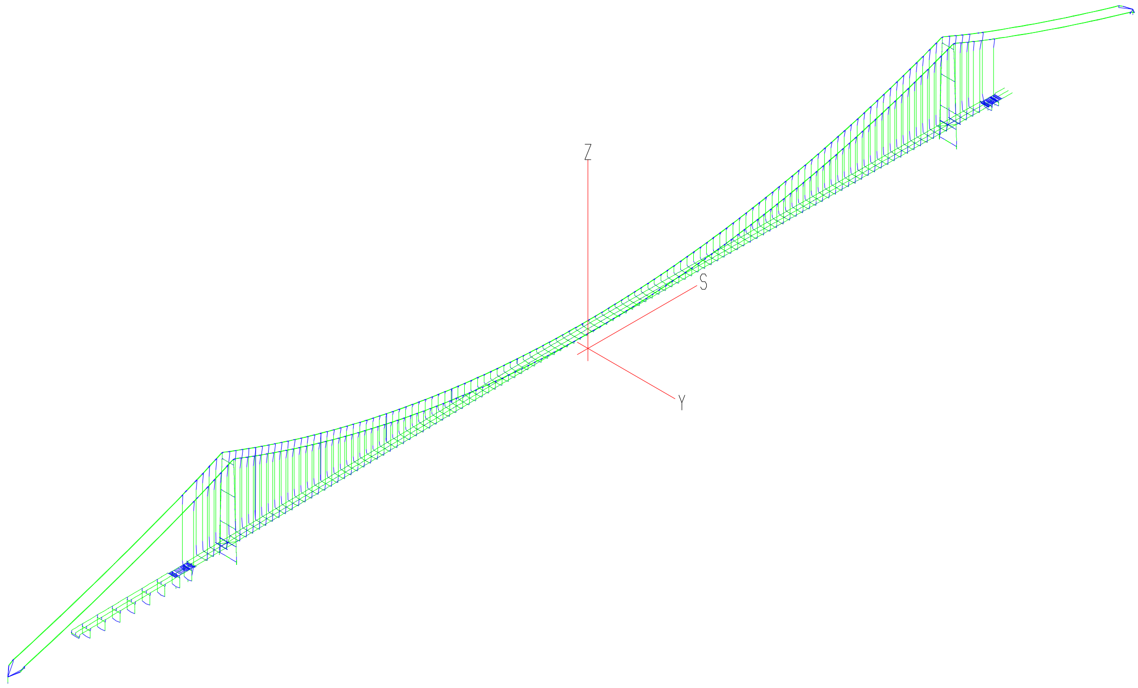

Figure 4-1: Global coordinate system in IBDAS

With this model the load, movements and rotations relevant for the bearings are determined. For further information please refer to [21].

4.1.1 Output from IBDAS

The following types of analysis are available from IBDAS:

- Static analysis (dead load, live load, wind and temperature loads);
- Seismic response spectrum analysis;
- Dynamic wind analysis (spectral analysis);
- Seismic time-history analysis;

The static, response and spectral analysis are carried out for two static systems: "free-free"; "fixed-fixed".

The type of static system refers to the condition of the longitudinal restraint of the suspended deck at the towers. In the "fixed-fixed" system the longitudinal restraint is blocked providing a rigid connection between the deck and the tower. In the "free-free" system the deck can move freely relative to the tower.

In the "free-free" static system a spring corresponding to the buffer characteristic is implemented in the longitudinal direction. The spring stiffness is 33 kN/m.

In both the "free-free" and the "fixed-fixed" static systems the transverse buffers at the towers are fixed providing a rigid transverse connection.

Based on the type of analysis and static system four limit states are available:

- SLS1
- SLS2
- ULS
- SILS

The limit states are defined in [1]. Further information concerning the IBDAS model is given in [21].

4.1.1.1 Seismic response spectrum analysis

The ground motion is defined for the four defined limit states, as given in the [1], the difference between the limit states being the peak ground acceleration.

The response of the structure subjected to the ground motion is calculated using the mode superposition response spectrum approach. A uniform ground motion is assumed, i.e. all supports are excited in the same manner. The damping ratio of the entire structure is taken as 5% relative to critical reflecting that large amplitude motions may occur during an earthquake.

The response spectrum analyses are carried out for the 1760 lowest modes of vibration in order to achieve a participating mass of more than 90%.

Results are provided for each of the four limit states. The principles as described above for the contribution from the uniform temperature load apply.

4.1.1.2 Dynamic wind analysis

The dynamic wind analysis consists of eight different load cases for each limit state of which the most adverse is used. The eight load cases are based on the wind direction in relation to the global IBDAS coordinate system, see Figure 4-2:

- mw 1: y+
- mw 2: s+
- mw 3: y-
- mw 4: s-
- mw 5: s+ y+
- mw 6: s+ y-
- mw 7: s- y+
- mw 8: s- y-

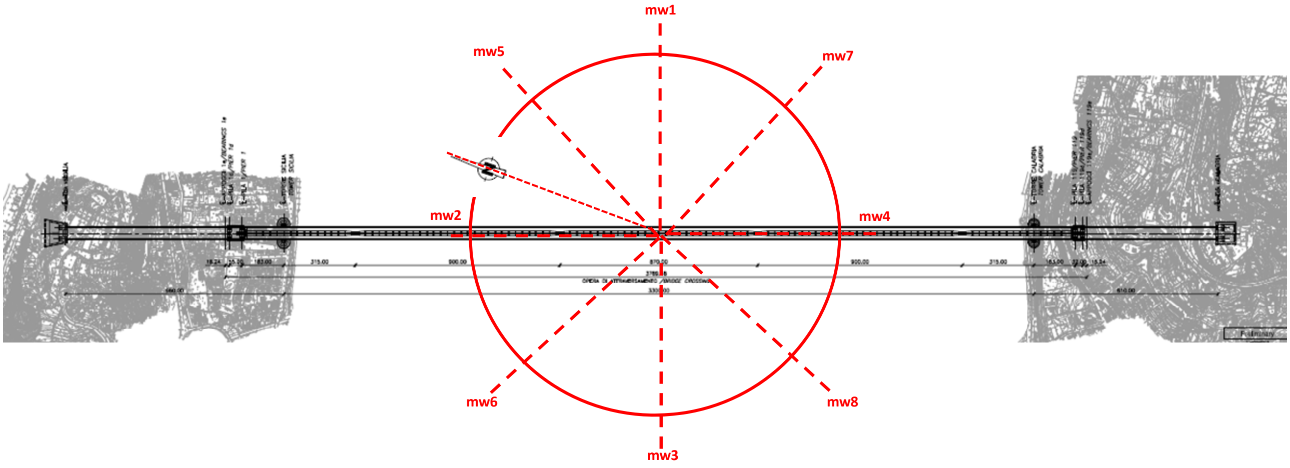

Figure 4-2: Definition of vind direction

4.1.1.3 Seismic time-history analysis

Time series compatible with the ULS design response spectra are used as seismic inputs for the time-history analysis.

There are in total 8 sets of time series, which have been analysed during the design.

Each set consists of three orthogonal components: two perpendicular horizontal components and one vertical component. The following two combinations are considered:

- 1.0 longitudinal component + 0.8 transverse component + 0.75 vertical component;
- 0.8 longitudinal component + 1.0 transverse component + 0.75 vertical component.

For the two combinations the results from the 8 sets of time series are averaged in accordance with [1].

Only dead load is included in the analysis. The results are therefore combined with the remaining relevant load given in the following load combinations:

- Primary structural components:
  - ULS: 6903
  - SLS1: 6913
  - SLS2: 6923
  - SILS: 6933
- Secondary structural components
  - ULS: 6568
  - SLS characteristic: 6668
  - SLS frequent: 6759

The damping coefficient is currently determined based on the important modes for the towers.

In the seismic analysis based on time-history analysis the buffers will operate in accordance with their characteristics.

4.1.1.4 Seismic time-history analysis with preload

As the buffer arrangement at the towers provide different spring stiffness depending on the actual position of the buffer the sequence of loads will have influence on the response from the buffers.

To take this into account the buffers are preloaded before application of the time series, thus simulating temperature and traffic conditions at the time of the seismic event. The traffic is placed at the most adverse position for a given structural element. For the buffers the traffic can for example be placed in such a way that buffers are given the highest tension possible due to traffic load.

4.1.1.5 Uniform temperature

The contribution from temperature gradients is included in relevant envelopes in both static systems. The contribution from uniform temperature however is not included in any envelopes and can only be found as an individual load case, which is added manually to the envelopes.

The contribution from uniform temperature is taken from the "free-free" static system. The reason for this is the fact that the nonlinear behaviour of the buffers can only be modelled correctly in the time-history analysis. The load from uniform temperature will exceed the threshold value of the buffers, requiring a change in the static system.

4.1.2 IBDAS output used for the bearings

The load on the bearings is found based on an envelope of all load cases in the static, the response and spectral analysis carried out in the "free-free" respectively the "fixed-fixed" static system.

The seismic analysis based on time-history analysis with preload is used for determining the movement in the bearings. The preload is based on the following conditions:

- Maximum uniform temperature;
- Fixation of the traffic loads such that there is maximum pulling force in the longitudinal buffers at the towers.

5 Basis of design for bearings

The basis of design for the bearings relating to load, movement and rotations can be found in [26].

The movement and rotations are multiplied with a factor of 1.10 in accordance with [2] section 10.5.

Appendix 1 - Mageba

In Appendix 1 is attached a preliminary assessment of the required bearings. This assessment has been done based on previously calculated bearing loads and have not been updated according to the latest calculated loads, which are included in the drawing CG1000-P-DX-D-P-SS-A0-AP-00-00-00-01, Articulation system - Bridge bearings, Overview

The detailed design verifications will be included during Progetto Esecutivo.